Tilt-Up Construction

. . . a modern method of building with reinforced concrete

PORTLAND CEMENT ASSOCIATION 33 W. GRAND AVE., CHICAGO, ILL.

What Is Tilt-Up?

TILT-UP construction is a special form of precast concrete construction. As used in this booklet, it is limited to construction in which the walls are cast on the site in a horizontal position, tilted to the vertical position, set in place and made an integral part of the completed structure. There are a great many different ways of designing and erecting such structures, particularly as to the details. Each designer and builder has his own methods and details which he is constantly trying to improve. It is the purpose of this booklet to show some of the practices which have proved satisfactory and to point out some to be avoided. The methods and details shown should not be considered as the only satisfactory ones but they will be helpful in developing details and procedures most suitable for a specific job and for the personnel and equipment available. It will be advantageous for the designer to consult with possible contractors before the design and construction details are definitely established. He should at least consider the personnel and equipment available in the area. Even small changes in design or construction procedure may result in appreciable saving in time and money as well as providing a better structure.

Front Cover—
A small industrial crane is tilting these 12-ft. high 6-in. thick panels. A 6x6 angle distributes the lifting force along the top edge of the 18-ft. wide panel. In the panel in the foreground, a yoke of 2x6 and 2x12 planks has been used to stiffen the 2x6 edge forms.

HISTORY

TILT-UP construction is generally considered as a new development because most of the buildings erected by this method have been built since about 1946. Actually, the method was used prior to 1912 and for a few housing developments and buildings of various other occupancies built between 1912 and 1946.

Most buildings constructed by the tilt-up method are one story in height, although there are some up to eight stories. Generally the multistory buildings have been constructed by tilting the walls for one story, placing the floor above, and then repeating the process. In some instances walls two stories in height have been cast and tilted as a unit. In fact, one of the earliest examples of tilt-up construction had the two-story walls cast on a platform which was tilted with the wall.

Various schemes have been tried using tilting platforms but by far the most common method is to cast the wall panels on the concrete floor, using the floor as the bottom form, and then tilt them into position.

Improvised hand equipment was used for tilting early jobs. At the present time most of the tilting is done with various types and capacities of power equipment ranging up to specially built machines capable of handling loads of 50 tons.

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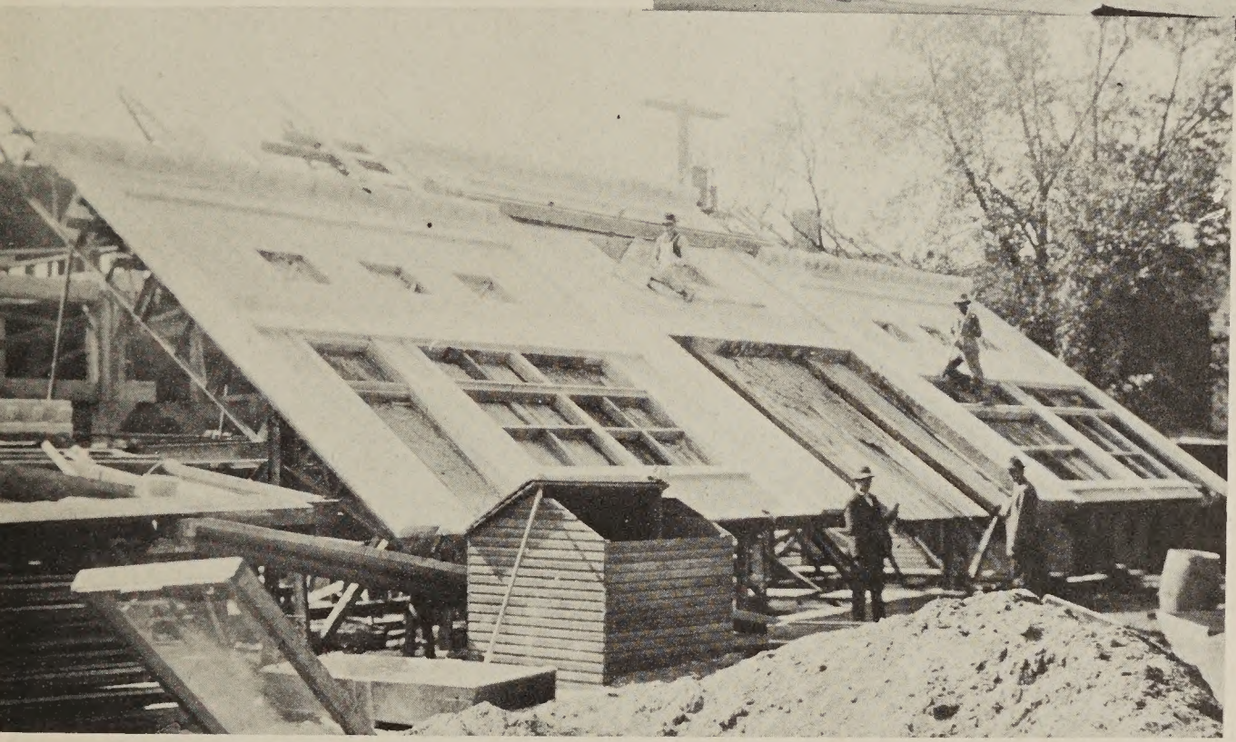
This building, photographed in 1947, was built by the tilt-up method at Des Moines, Iowa, between 1906 and 1912. Below is shown the front being tilted. The platform on which this wall was cast was tilted with the wall. Some of the walls are hollow, made by casting a 2-in. layer of concrete, placing a 2-in. layer of sand and then casting the top 2-in. layer of concrete. The two layers of concrete are tied together with reinforcement. The sand was washed out with a fire hose as the wall was tilted.



In 1912 several buildings were erected of tilt-up construction for the Army at Ft. Crockett, Galveston, Texas. This is one of the houses photographed in 1951. Willard E. Simpson, architect.

Owen Building, Columbia, S.C. The frame and floors for this building were erected in the usual manner and then the wall panels cast on the floor, and tilted into position. The walls are composed of 2 in. of regular concrete and 6 in. of vermiculite concrete. Lafaye, Lafaye and Fair, architects. R. C. Johnson, engineer. General Construction Company, contractor.

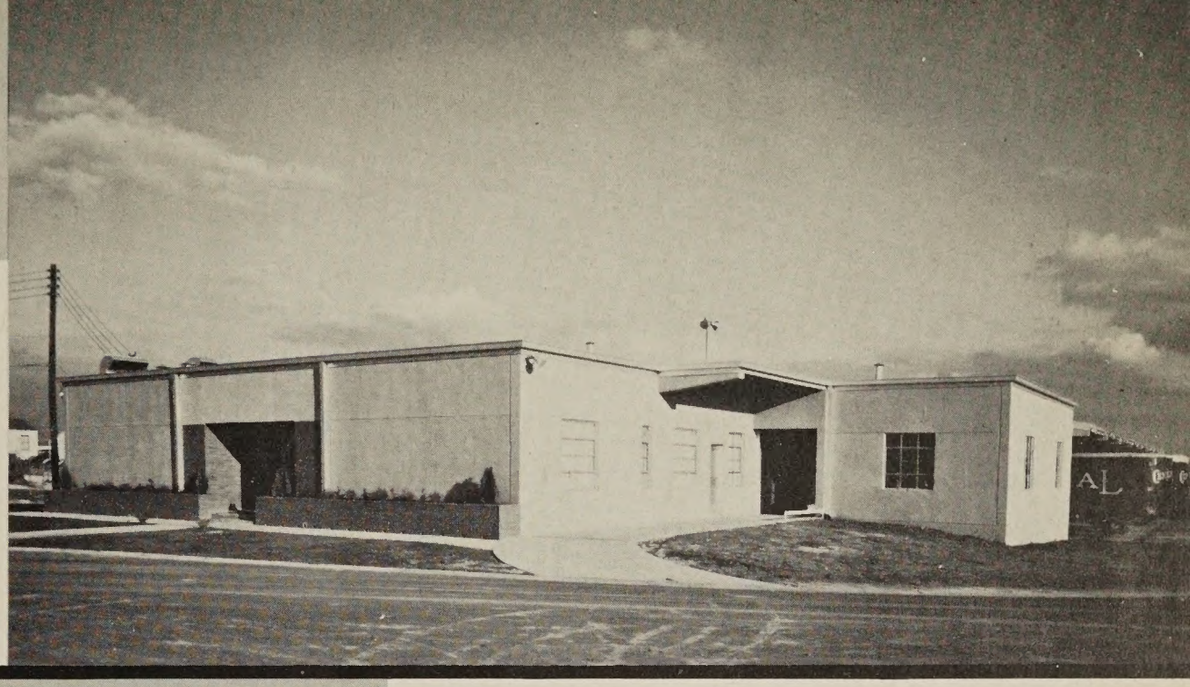
ADVANTAGES

TILT-UP is adaptable to a wide range of uses and architectural effects. It has been used for many types of structures from private homes and garages to multistory office buildings, although by far its greatest use has been for one-story industrial and commercial buildings.

Construction time is relatively short with this method. Time-consuming form construction or setting of thousands of small units is avoided. As an example, for a 45x80-ft. building, a crew of eight inexperienced men set the forms and cast the panels in one day and erected them complete with wall columns in two days.

In the very important matter of cost, tilt-up construction also has advantages. It is always unsatisfactory to give general cost figures or comparisons as varied design requirements and local conditions influence cost on each job. However, in nearly every instance where competitive bids have been taken, tilt-up construction has been bid lower than any other comparable wall.

Office building of Southern Express Company, Dallas. Herman Cox, architect. McFadden and Miller, contractor.



This view shows the office portion of the Central Freight Lines Terminal at Fort Worth, Texas, one of several tilt-up buildings erected for this company. W. E. Lessing, architect. Joe Caulker, contractor.

DESIGN

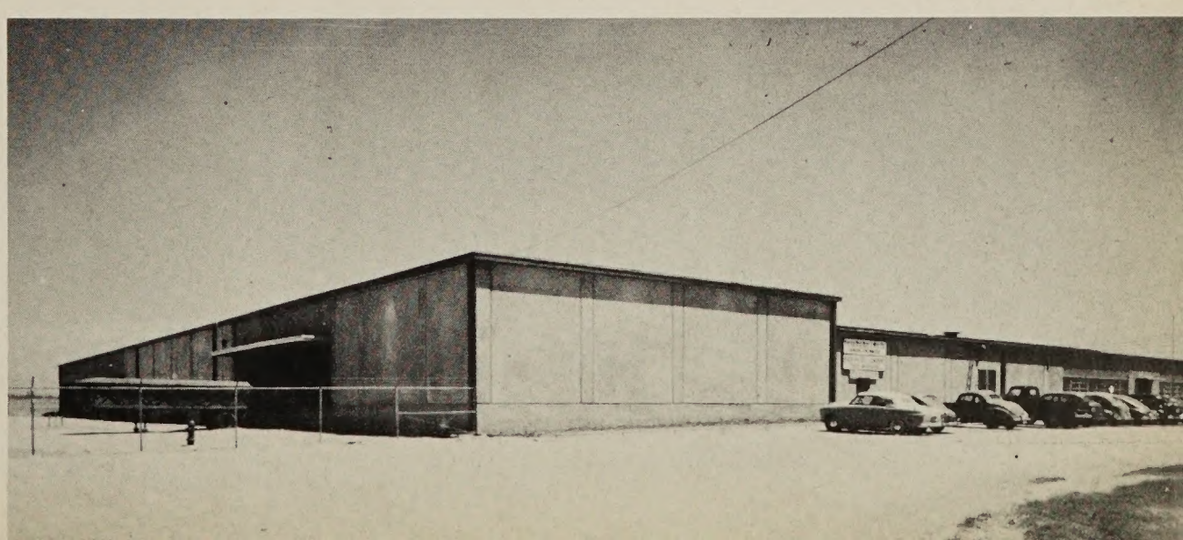
Wall panels must be designed for the conditions to which they will be subjected in the completed structure and during erection. The general design of the building will determine whether the walls are load-bearing or non-load-bearing with a continuous footing or supported on the column footings only. The design for these conditions after the walls are in position will be little if any different than for walls of reinforced concrete built in the conventional manner. The only difference will be in details.

Sometimes it is economical to consider the wall panels as deep beams spanning between the columns. Some builders cast panels to extend from pier footings to parapets. In buildings with floors at dock height, the lower portions of these panels are designed to retain the compacted fill on which the floor is placed.

Lifting Stresses

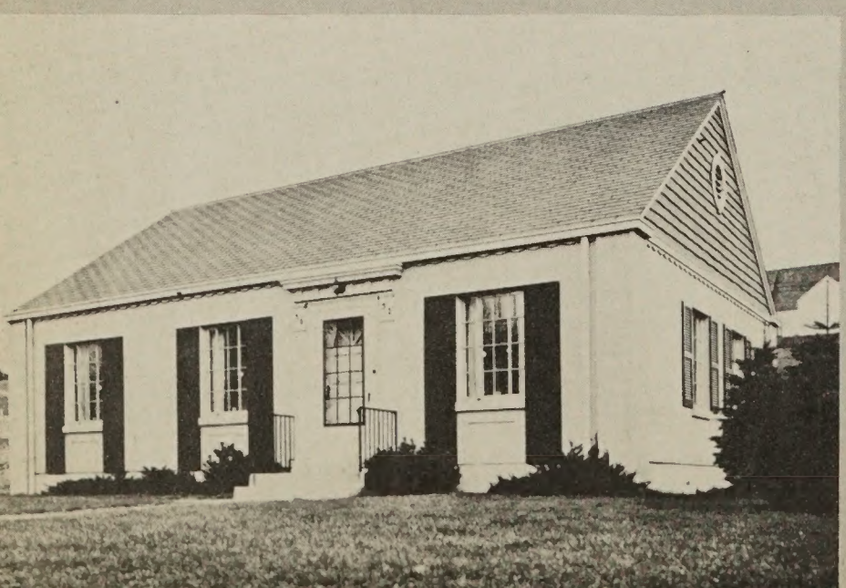
Tilting a wall panel creates stresses not encountered in conventional cast-in-place construction and with some pickup arrangements an exact analysis may be rather involved. The method of attaching the lifting equipment must be known in order to determine the stresses. If the attachment is to a stiff channel or angle bolted to the top edge of the panel, the latter will be designed as a simply supported slab.

With a 2-point pickup along the top edge, the maximum positive moment in a solid panel will occur along a horizontal line at about mid-height of the panel, and can be determined with reasonable accuracy by considering the panel as a slab simply supported along the top and bottom edges. The intensity of this moment will vary along the centerline of the panel with the maximum occurring opposite the pickup points. With the pickup points at the quarter points of the top edge, the maximum intensity of positive moment will be only about $0.15wh^2$ even for a panel having a width twice its height. The maximum



Wholesale grocery warehouse of Hale Halsell Company at Tulsa, Okla. David R. Graham, architect. Tulsa Rig Reel and Manufacturing Company, contractor.

Tilt-up construction can be used successfully in the construction of houses with a wide range of architectural styles.



negative moments occur on lines approximately from the pickup points to the nearest lower corners of the panel with the maximum intensity near the pickup points. The maximum negative moment will be about $0.11wh^2$ for a square panel and will increase to about $0.32wh^2$ for a panel twice as long as it is high. In these formulas w is the weight per square foot of wall and h is the height in feet. To reduce this high negative moment in long rectangular panels, it is obvious that it will be desirable to move the pickup points toward the corners. Using more than two pickup points will reduce both the maximum positive and maximum negative moments.

It is assumed that a spreader is used on the pickup lines so that the lifting force at the pickup points is vertical. If this is not done the moment between pickup points will be greater than indicated above.

The lifting stresses can be reduced considerably by placing the pickup points some distance from the top edge. Locating the points one-quarter of the way down instead of at the top edge reduces the moments about 60 per cent.

Strongbacks have been used very satisfactorily on many jobs. However, their benefits are primarily due to lowering the position of the top attachment points. Attachment points close to the bottom edge have little effect upon the moments. The effect of additional intermediate points of attachment will depend upon the relative stiff-

Maxcy Gregg Park Bathhouse, Columbia, Ga. The canopy is an extension of the reinforced concrete roof. The building was designed by the city and built by General Construction Co.

ness of the panel and the strongback. With panel and strongback of normal size the panel is so much stiffer than the strongback that little load will be carried at intermediate points. In fact, if the lifting equipment is attached to the strongback an appreciable distance beyond the top attachment to the slab, the strongback may deflect enough to press down on the slab rather than lift it at the intermediate points. Even an infinitely rigid strongback would have little effect on moments in the longitudinal direction, which are the important ones in panels of greater width than height.

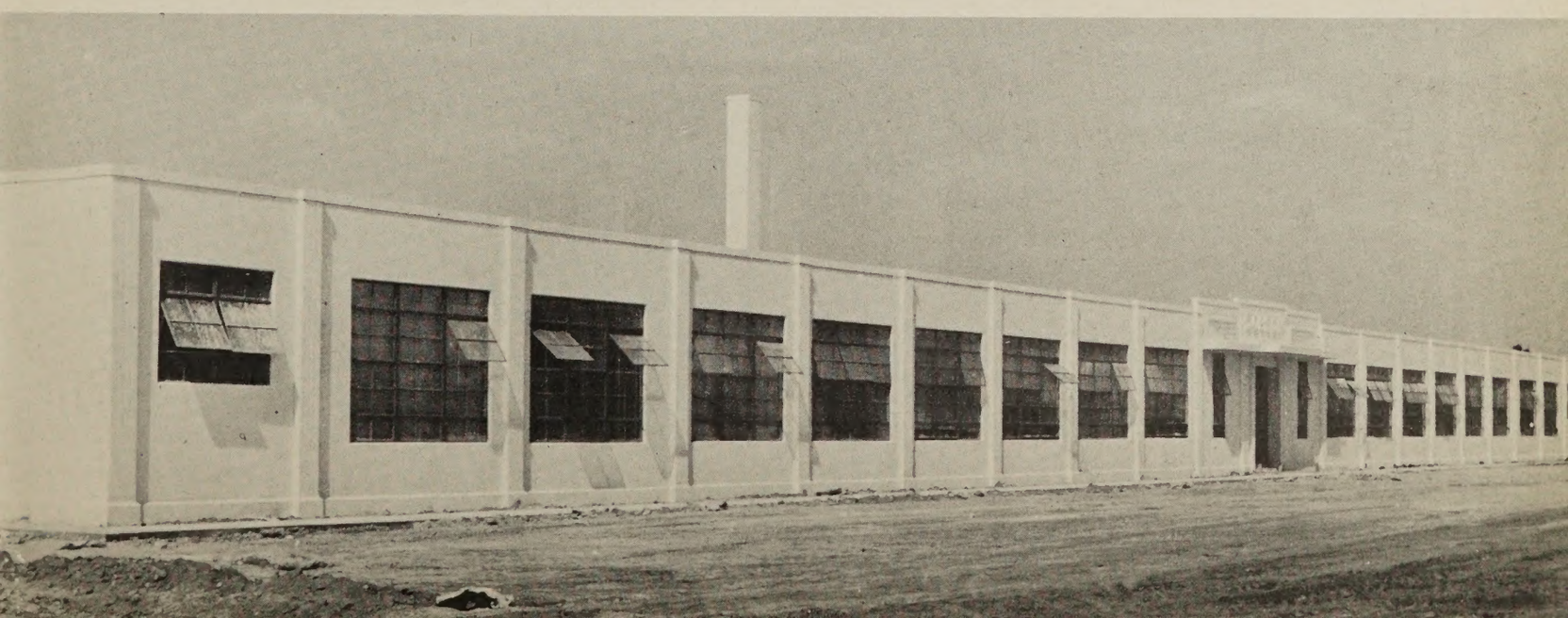
Strongbacks are advantageous where openings in the panel appreciably reduce its strength at critical sections.

Stiffening members bolted to the sides or to the sides and top of a panel will reduce the bending moments within the panel for the same pickup points. The amount of the reduction will depend upon the stiffness of the frame, shape of panel, and location of pickup points. With side members only, the vertical positive moments will be reduced but there will be little reduction in the horizontal moments. Side members will be advantageous for relatively high panels where the vertical moments are greater than the horizontal moments. With the frame on the sides and top, all moments will be reduced as compared with those occurring in a panel without frame and with pickup along the top. Frames are particularly advantageous for panels with large openings.

Openings present an individual design problem for each size and location. However, a rule-of-thumb which is satisfactory for ordinary conditions is to consider the actual weight of the panel as distributed over the total area including openings. The steel which would normally extend through the openings is concentrated at the sides of the openings, both horizontally and vertically.

Higher unit stresses may be allowed for lifting than for other design purposes. Lifting stresses occur only during tilting and at no other time. It is therefore considered satisfactory practice to use a unit design stress approaching the yield point of the reinforcement. Even though sufficient steel is provided to prevent failure, it is good practice to make sure that the flexural stress in the concrete when computed for the transformed section is below the modulus of rupture strength (approximately $0.1f'_c + 200$).

Dobson Elementary School, Lancaster, S.C. was designed and built by T. W. Belk. The section at the entrance was cast in place.



Tilt-up construction was used for most of the buildings in the 93 acres of this Los Angeles International Airport Industrial Tract. Hayden-Lee Development Company, owner-contractor. S. Charles Lee, architect.

Loads

The total load to be used in computing erection stresses must be assumed. In addition to the dead load of the slab, there is some resistance to the initial movement, the amount depending on the type of bond prevention material, surface condition of the floor, moisture condition, lifting speed and possibly other factors. Experience indicates that where care is taken to prevent bond between the panel and floor, the initial resistance to movement is only slightly greater than that due to the weight of the slab.

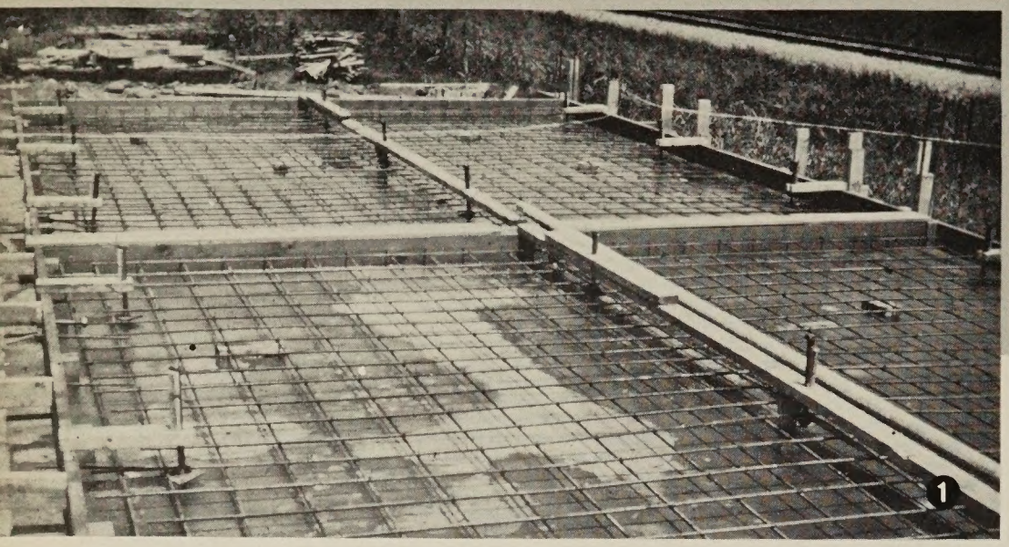
Some contractors use jacks to break the initial bond by moving the panels horizontally or by raising them off the floor slightly. Jacking not only reduces stresses by breaking the bond slowly but also by eliminating the whipping or bouncing that sometimes occurs with long leads when the panel breaks free from the floor slab. Preliminary breaking of the bond also allows the use of lighter tilting equipment. Although jacking has some advantages and may be desirable on some jobs, it is not necessary for most conditions.

The most common wall thickness is 6 in., nominal or actual, because this dimension generally meets structural requirements and is such that average-size panels can be erected without extreme care. Using the nominal dimension results in an appreciable saving because 2x6 dressed lumber can be used for the edge forms.

Warehouse and office of Northern Drug Co., Fargo, N.D. The panels for the first story walls were cast and tilted. Then the second floor was cast and the procedure repeated. Oliver Stoutland, architect. Meinecke and Johnson, contractors.

These three buildings show the use of tilt-up construction combined with cast-in-place architectural concrete. The street fronts of the buildings are cast in place while the remainder of the walls are tilt-up. For the Safeway store at Ft. Worth, Texas, the architect was Smith and Warder and the contractor was Cain and Cain. The office and warehouse of Kessler-Simon Machinery Company at Oklahoma City, Okla. was designed and built by Boecking Company. The Wilson Motor Company salesroom and garage at Columbia, S.C. was designed by William Morgan, engineer, and built by General Construction Company.

The Sequence of Tilt-Up

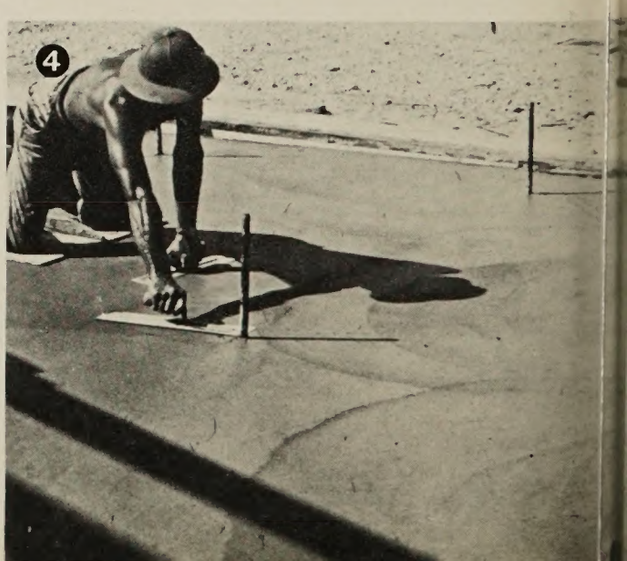


1. This shows the construction ready for the concrete. The edge forms have been placed on the concrete floor slab, bond prevention material sprayed on the slab, reinforcement placed and inserts set. By using short bars for dowels to the columns, the reinforcement can be made as a mat on a jig outside the forms and placed as a unit. This also reduces scuffing the bond prevention material. The blocks under the reinforcement are removed as the concrete is placed. Bolts for attaching a strongback are held in place with templets of 2x4 and 2x6.

2. The concrete is being placed and screeded.

3. The concrete has stiffened sufficiently to permit the templets to be removed and the surface leveled with a darby. This panel has a metal window frame cast in it. The other two openings are simply framed with 2-in. material.

4. and 5. The surface is finished by troweling and brushing.



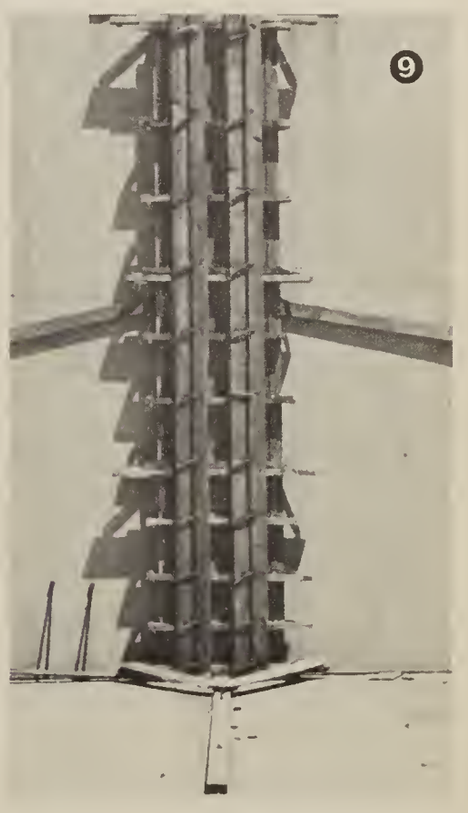
Operation in Construction

6. The panel is being tilted into position after which it will be braced as are those in the background until the columns are cast.

7. Here is the other side of the tilting panel. The workman is placing the mortar on which the panel is set. The 2x4 wales attached to the foundation are used to align the bottom of the panel.

8. The dowels have been wrapped with paper to prevent bond with the cast-in-place concrete column. The lifting bolts in the panel at the left have been removed. The bolt hole will be filled with mortar. Such patches are always darker than the cast concrete unless part of the regular cement is replaced with white cement.

9. The column forms are in place for casting the columns which is the final operation.



Grade beams are being cast on the ground. Fill will be placed against these slabs in their final position so that the rough finish on the bottom is not important.

CONSTRUCTION DETAILS

Casting Surface

The concrete floor slab generally serves as the casting platform, but occasionally a stationary wooden platform or a tilting platform has been used. Grade beams which must be made before the floor is placed have frequently been cast directly on a leveled area of ground.

The ideal platform is a level, smoothly troweled concrete slab. Pipes or other utilities to be extended upward through the floor slab may be stopped below the floor surface and the openings temporarily closed. The closure may be made by a flush wood plug, by filling with sand topped by a thin coat of mortar, or by any means which will give a flush surface. It should be remembered that any imperfections in the surface of the casting platform will show on the wall panel. If the floor has a decided pitch or depressions, it may be leveled with sand topped with a thin mortar coat or with a lean soil-cement fill. These temporary toppings are easily removed after the panels are raised.

Bond Prevention

Many materials have been used satisfactorily to prevent bond between the floor and the wall panels, but some have given consistently better results than others.

Bond-preventive materials may be divided into two general groups: sheet material and liquids. The latter are by far the more generally used.

Sheet Material. While ***paper*** and ***felt*** effectively prevent bond, they should not be used where the contact surface of the panel is to be left exposed or simply painted. At least a few wrinkles invariably occur in the paper and disfigure the surface of the panel. Paper and felt often stick to the panel and in some cases are difficult to remove. Paper or felt impregnated with asphalt or having a layer of asphalt may stain the panels.

Sheets of plywood, tempered fiberboard and metal, when oiled or otherwise properly treated, are effective in preventing bond and may be reused many times when handled with reasonable care. Their disadvantage is the initial cost and the joint marks left on the wall panels. The marks may not be objectionable if they occur in a regular pattern.

Canvas gives a very pleasing texture and has been used successfully where the panels are lifted at a very early age as can be done with vacuum lifting mats. After concrete has hardened sufficiently for handling the panels by other methods, it is very difficult to remove the canvas even though it has been treated. The canvas should be dusted with cement or sprinkled with water just prior to placing the concrete.

Liquids.* Some *general rules* apply to the use of all liquids used for bond prevention. A sufficient quantity must be applied to seal the floor surface and prevent

*It is understood that patents have been issued relating primarily to the use of certain liquid materials for bond prevention.

bond with the wall panel. A considerable excess should be avoided as it tends to discolor the wall panel. The material should be applied in two or more coats. The first coat or coats should seal the floor surface completely and leave no dry spots. The final coat should be applied only a relatively short time before the concrete is placed so that material and workmen will not scratch or scuff the final film. Marks and footprints on this film may show on the finished panel. The material may be applied with a swab, brush or spray.

Sometimes different materials are used for the first coat and final coat. As an example, curing compound has been used for the first coat and spirit wax for the final coat.

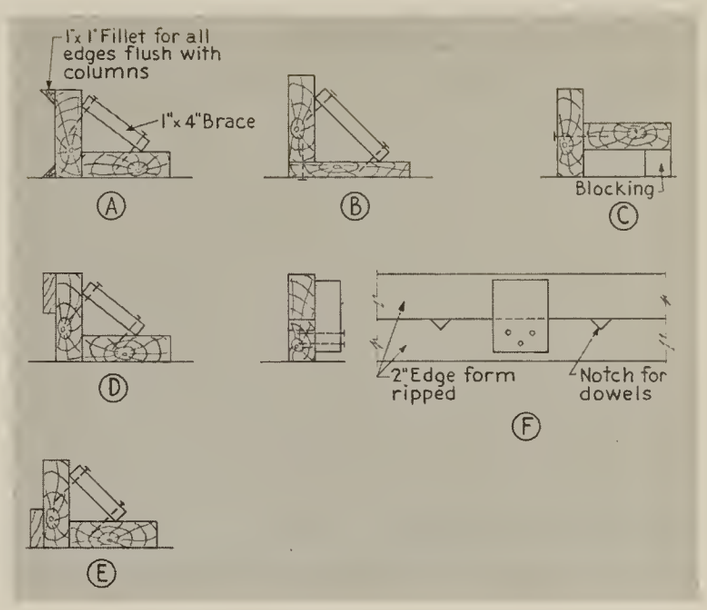
The liquid must be kept off reinforcement so that bond between the concrete and reinforcement will not be reduced.

The common types of *form oil* have given good results when properly used. The concrete floor must be dry when the oil is applied and the oil must be allowed to dry before the concrete panel is placed. If the oil is not sufficiently dry it will float up into and stain the concrete and will not prevent bond.

Several of the special *form treatment materials* have been used with good results.

Curing compounds have been used very successfully on many jobs. The first coat should be applied as soon as the concrete floor has been finished and will then serve the dual purpose of assisting in curing the floor and of breaking the bond between floor slab and wall panel.

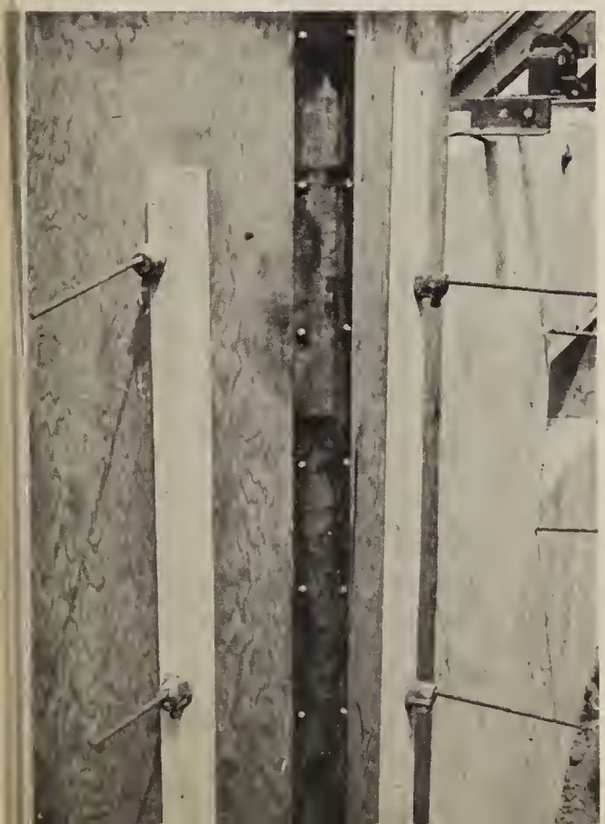
A special **spirit wax** has been used on several jobs with excellent results. Ordinary liquid floor wax has also been used successfully.



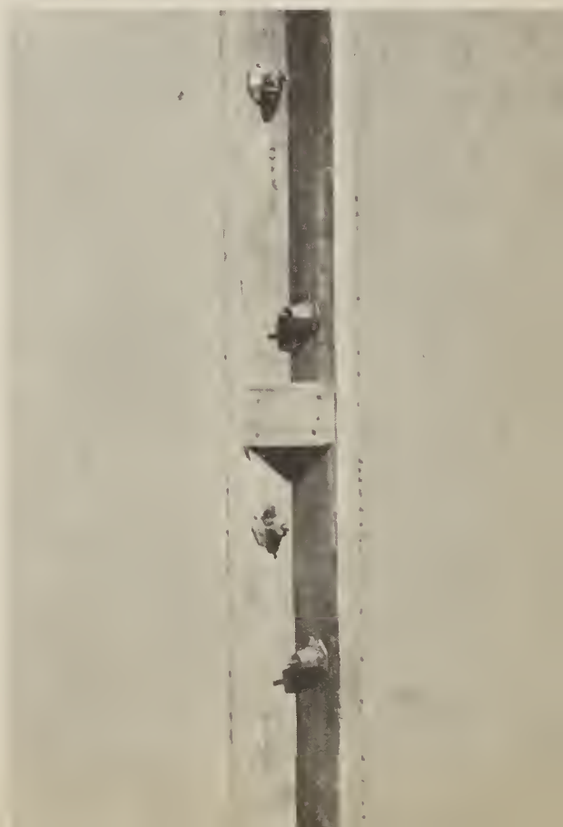
Edge Forms. ***A, B*** **and** ***C*** **show basic arrangements of edge forms made of 2-in. lumber. Fillets as shown in** ***A*** **should be used wherever the face of the panel is flush with the column. Extra strips may be used as in** ***D*** **and** ***E*** **when offset edges are desired. Ripping and notching the edge form for dowels and bolts as in** ***F*** **permit easier stripping than boring holes even though they are considerably oversize.**

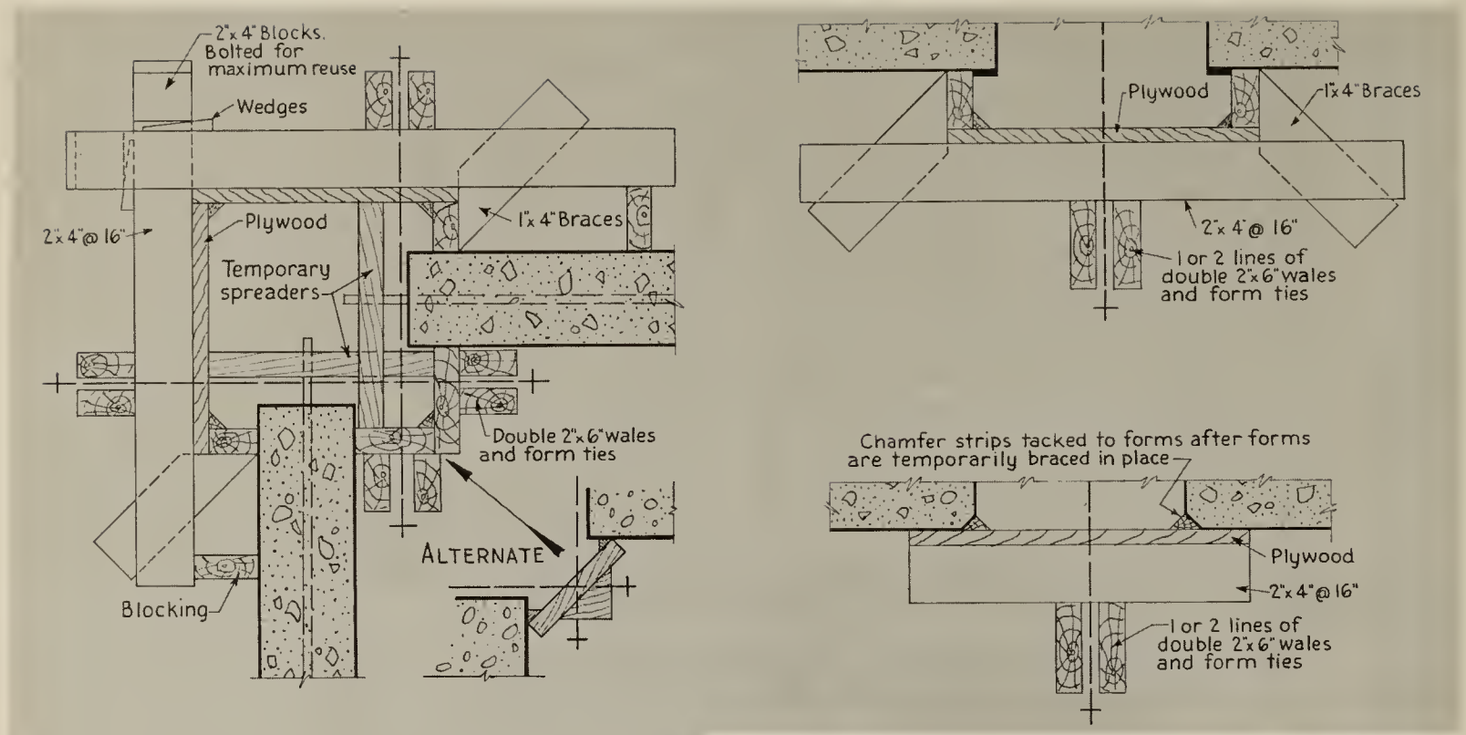
Liquid soap has been satisfactory but requires special care to be sure the proper amount is used. In some cases an excess of soap has reacted with the fresh concrete so that the finished surface of the wall panel has been sandy.

There are also *materials specifically prepared* for this



Simple forms can be used for corner columns which are flush with the wall surface on both the inside and outside. On this job the two pieces of plywood for the outside column faces are fastened together with an angle screwed to the plywood and are handled as a unit. The plywood is stiffened between ties with a 2x4. A 2x4 and 2x6 fastened together and handled as a unit are used for the inside form.





Column Forms. **Column forms which can be easily erected, stripped and reused are of importance to economical tilt-up construction. These few typical details may be modified to fit many conditions. A wire through a hole near the end of the temporary spreaders will aid in and assure their removal.**

purpose. Some of these have given excellent results and in certain parts of the country are used practically to the exclusion of other materials.

Some job-mixed materials have also given good results. Among these is a mixture of 5 lb. of paraffin in 1 to 1½ gal. of light oil or kerosene. The oil must be heated to dissolve the paraffin.

Forms

Forms for the sides of panels are usually made of 2-in. lumber but in a few cases steel angles or channels have been used.

Regardless of the material used, edge forms must be sufficiently stiff and well braced to remain in good alignment. This is particularly true of those forming the top and bottom edges of the panel. When side edges of panels are completely encased in cast-in-place concrete, any irregularities in these edges will be covered by the columns. The top of the forms should be in the same plane so that they can be used for screeds.

Edge forms for the sides must have holes for the dowels which extend into the columns. The holes should be ¼ in. larger than the dowels to permit easy stripping. Sometimes the forms are split on the line of these holes to make removal easier.

For doors and windows, the finished frames or rough bucks may be cast in the panels, or openings may be prepared by using forms similar to those for the panel edges. The frames or forms are held in place by fastening to the edge forms or by loading them with sandbags or heavy blocks of concrete.

When wood frames or forms are to be used, provisions should be made in forming all openings in the panels so that swelling of the wood will not start corner cracks in the concrete. Where the dimension of the opening is not more than about 4 ft., a piece of edge grain lumber in the corner will absorb enough of the expansion of the

Special precast concrete units have been used to replace exterior column forms and to give the same surface texture as the panels. In the middle of the photo to the left is a newly cast unit. The surface which will be exposed is on top so that it can be finished the same as the wall panels. The unit in the foreground shows the wire loops which hold the unit in place temporarily and tie the unit to the cast-in-place column. In the background is a stockpile of the units. The photo at the right shows the column forms ready for placing the concrete. Tierods extend through holes cast in the tilt-up panels. The difference in color of the tilt-up panels and the precast column form is due to the difference in age and moisture. The color was uniform by the time the job was completed.

frame to prevent cracking. For larger openings, the expansion can be absorbed by a splice in the frame. This is made by cutting diagonally through the frame and then lightly nailing the pieces together.

Although many steel window frames are cast in the wall panels there are several advantages in placing the frames after the concrete has hardened even though there may be a slight increase in cost. This is particularly true in moist climates where the steel may rust and cause distortion of the frames or spalling of the concrete. In such climates, frames cast in the concrete should have at least a coat of paint applied on the job in addition to the shop coat.

Many methods are used to keep edge forms from spreading. They may be tied together by ¼-in. rods and form tie fittings or by wire running between opposite edges in the plane of the reinforcement or they may be braced on the outside. The latter is more common. The forms for panel sides can be braced against the sides of adjacent panels. Frequently column bars projecting above the floor can be used to brace the form for the top and bottom edges. Inserts or temporary bolts set in the floor slab can be used for bracing the forms and later for attaching temporary braces to hold the tilted panels in position. Considerable stiffness can be added to edge forms by backing them with 2-in. members laid flat on the floor or blocked up to form a T or channel. Where there is considerable repetition of the panel sizes, the stiffening members may be nailed to the edge forms so that they can be handled as a unit.

Temporary wood ties or braces may be nailed across the top of the forms until the concrete has been placed. These are particularly helpful in keeping the corners square.

Reinforcement

As mentioned in the sections on design, the walls must be reinforced as conventional reinforced concrete walls and also to provide for the stresses due to lifting. The reinforcement may be supplied in the form of bars or welded wire fabric or a combination of the two.

When welded wire fabric is used, bars must be used as dowels between the wall panels and the columns. Even with bar reinforcement, some contractors prefer to use extra bars for dowels. This permits the reinforcement to be assembled as mats outside the forms and placed in the forms as a unit. Mats can be assembled rapidly on a jig and the use of mats greatly reduces walking on the floor which has been treated with the bond preventive. If wire fabric is used in panels with openings, it is usually placed in sheets covering the entire area and then clipped along the edges of the openings.

As with any reinforced concrete construction, a large number of small bars gives better crack control than the same weight of larger bars. However, the small bars cost slightly more per pound and require a little more time to place.

Extra reinforcement should be used at openings. The bars may be parallel to and about 2 in. from the sides of openings or may be placed diagonally across the corners of openings. Diagonal bars interfere less with concrete placing in walls cast flat than in those cast in place. They are also somewhat more efficient than parallel bars in preventing corner cracks. The minimum extra reinforcement should be one ⅝-in. bar extending at least 2 ft. beyond the corners of the opening.

The reinforcement may be supported in the conventional manner used for floor slab reinforcement or may

Blocks of concrete, which have proved very useful on tilt-up jobs, are being used here to hold window and door frames in place and to hold the side forms in alignment. This reduces the amount of bracing and thus saves considerable time and material as well as reducing interference with placing and finishing the concrete. A rod slipped through the two loops on the blocks permits two men to handle them easily. These are much more satisfactory than sand bags which sometimes are used in a similar manner.

be suspended from members laid across the edge forms. These temporary supports may be removed before final screeding of the concrete so as not to interfere with this work. Steel chairs should not be used when the bottom surface of the panel will form the outside face of the wall.

Utilities

Electrical conduits and outlets can be placed in the forms and cast in the concrete. Where there is a horizontal run across two or more panels the conduit can be extended through the edge forms the same as dowels. There are several compression-type fittings which can be used to connect the conduit from adjacent panels in the column space. The conduit and outlets can be held in place during the placing of the concrete by wiring and wedging them to the reinforcement.

Concrete

Quality. The concrete must be of a quality which will withstand weathering and so should contain not more than 6½ gal. of water, including surface water carried by the aggregate, per sack of cement. Since the concrete is placed with the panels in a horizontal position, a stiffer mix and larger size aggregate can be used than in walls cast vertically. A minimum of 5 sacks of cement per cubic yard of concrete with 1½-in. aggregate should give a satisfactory mix.

Placing. The concrete is placed and finished the same as in a floor slab. Extra care should be taken to prevent honeycomb along the bottom edges of the form and to prevent breaking through the bond-prevention material. The concrete is worked into place by spading or by vibration and is then screeded, floated and finished, using the same technique as for floors. The compaction and screeding may be combined by using a vibrating screed. A mechanical float is advantageous for finishing wall panels as well as floors.

Wall finishes. Many different finishes may be obtained economically when the wall is cast in the hori-

The walls of this Sears Roebuck and Co. retail store at Portsmouth, Va., are 8 in. thick including 2 in. of insulating concrete. The troweled exterior surface of the tilt-up panels is patterned by cutting with a center bead. The parapet wall is cast in place with the columns and has control joints at the center of each panel. F. E. Davidson was the architect and the concrete work was done by W. F. Magann Corporation.

Left—Schaubs Market, Temple City, Calif. F. Thomas Collins, engineer. Wohl-Calhoun Co., contractor. *Right*—Warehouse and office of Nunn Electric Supply Corporation at Houston, Texas. C. A. Newsome and L. S. Newsome, architects. Harold Van Buskirk and Co., contractors.

zontal position. Some of these are: smooth float, swirled float, hard troweled, brushed or broomed, patterned, colored and ground. Regardless of the finish used, workmen must be cautioned to do the finishing of all panels and all parts of each panel in a uniform way. A spotty effect will result if, for example, part of a panel is troweled more than other parts.

Many variations of float finishes may be obtained exactly the same as on floors and sidewalks. A fairly smooth float finish catches less dirt than a rougher finish. Troweling gives a smooth surface but increases the possibility of surface crazing and magnifies inequalities in finishing. In severe climates, the surface may gradually lose this smoothness on the most severely exposed portions so that a uniform appearance will not be retained over the entire surface. The grout-cleaning procedure described under "Column finishes" is advantageous on trowel-finished panels also.

A pleasing finish may be produced by drawing a brush or broom over the trowel finish. This tends to minimize any irregularities in the surface and removes laitance which may cause surface crazing. The amount of scoring or roughness may be varied considerably by varying the stiffness and coarseness of the brush or broom, the pressure on the brush, and the hardness of the surface at the time of brushing. Having the brush marks in the vertical rather than the horizontal direction of the panel reduces the collection of dirt and increases the washing effect of rain on the walls. For this reason any horizontal brushing should be very light.

Patterns may be made by cutting the surface with a center bead. A checkerboard effect may be obtained by

Here are three of the many tilt-up jobs built by the William P. Neil Company in Los Angeles from designs prepared by Reliance Engineers, Inc. In the foreground is the office and warehouse of General Electric Company. Next is the Hudson Sales Corporation and then Westinghouse Electric Corporation.

Warehouse of Stanley Home Products at Tulsa, Okla. C. R. Nuckolls, engineer. Horster, contractor.

combining the pattern with the brushed finish and lightly brushing adjacent sections in different directions.

Color may be obtained by adding a colored concrete topping before the base concrete hardens. Of course, the building can be painted but it must be remembered that once painted it must be repainted periodically to retain good appearance.

A ground finish may be given wall panels when in the horizontal position. The same methods are used as in finishing terrazzo floors.

Column finishes. A great variety of surface finishes are possible on wall panels, but the number of practical variations on the columns is quite limited. This should be considered in connection with the overall architectural effect. The most common finish on columns is the smooth surface obtained by using forms of plywood or other material in large sheets. Accentuated vertical board-marked surfaces can sometimes be used effectively. Fluting is also readily obtained by tacking milled wood strips on the inside of the forms.

The simplest, most economical and satisfactory final treatment for columns is a grout cleaning of the surface as follows:

Mix 1 part portland cement and 1½ parts fine sand with sufficient water to produce a grout having the consistency of thick paint. White portland cement should be used for all or part of the cement in the grout to give the color desired. Wet the concrete enough to prevent absorption of water from the grout and apply the grout uniformly with brushes or a spray gun, completely filling air bubbles and holes. Immediately after applying the grout, float the surface with a cork or other suitable float,

Warehouse of Merchants Transfer and Storage Co., Des Moines, Iowa. The wall panels for this 3-story building were cast on tilting platforms. After the first story walls were completed, the second floor was cast and then the cycle repeated for the second and third stories. Brooks and Borg, architects and engineers. Weitz Company, Inc., contractors.

scouring the wall vigorously. All excess grout should be removed by finishing with a sponge rubber float. This finishing should be done at the time when grout will not be pulled from holes or depressions. Next, allow surface to dry thoroughly, then rub it vigorously with dry burlap to completely remove any dried grout from the surface. There should be no visible film or grout remaining after this rubbing. The entire cleaning operation for any area must be completed the day it is started. No grout should be left on the surface overnight.

Curing. Curing of panels should be started as soon after finishing as possible without marring the surface and should be maintained until the concrete has attained the desired strength. Attention should be given to any possibility of staining or discoloration from curing, since even a slight amount is objectionable and will not wear away evenly on the vertical wall surface. The possible effect on bond for painting should also be considered.

Joints

Various materials and details have been used in making the horizontal joint between the wall panel and its supporting member. The most common material is portland cement mortar, but premolded joint filler has also been used either alone or in combination with mortar.

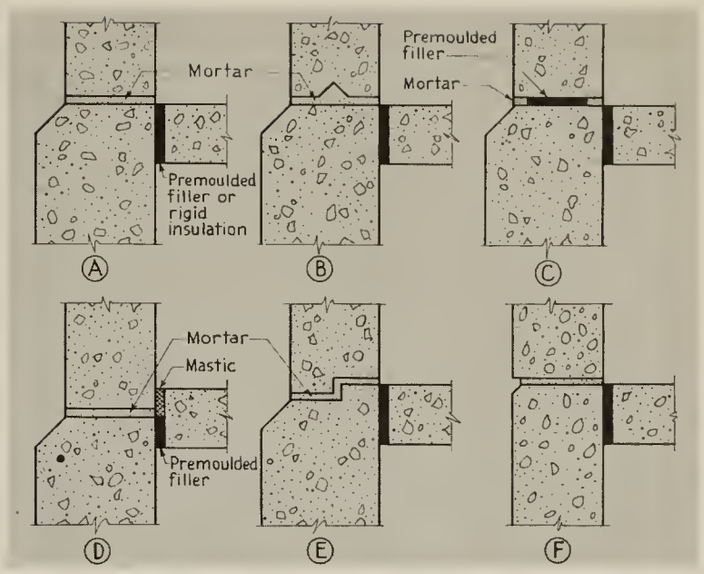
The simplest method of using mortar is to spread a layer of it on the foundation and tilt the wall onto the mortar bed. This gives a strong, watertight joint. The principal objection to using mortar is that the mortar may squeeze out unevenly and there is little opportunity for adjusting the level of the wall. With some details of columns and roofs, a small variation is not important. A refinement of this method is to place carefully leveled pads or blocks on the foundation. These will hold the panel at proper level until the mortar sets. The pads may be replaced by wedges which can be used to true the panel as it is being placed.

Another procedure is to set the panel on pads, blocks, or wedges and then fill the joint with mortar dry-packed into place. This permits easy and good adjustment of the panel but the expense of dry-packing is considerably more than spreading plastic mortar. Although some believe a tighter joint can be obtained by dry-packing, very careful workmanship is required to obtain a good job.

Sometimes the panel is set on a strip of premolded joint filler about ½ to ⅔ the thickness of the wall and the remainder of the joint is dry-packed. This permits quick setting of the panels and results in a tight joint. It has the disadvantages of not permitting adjustment of the panels and of being relatively expensive.

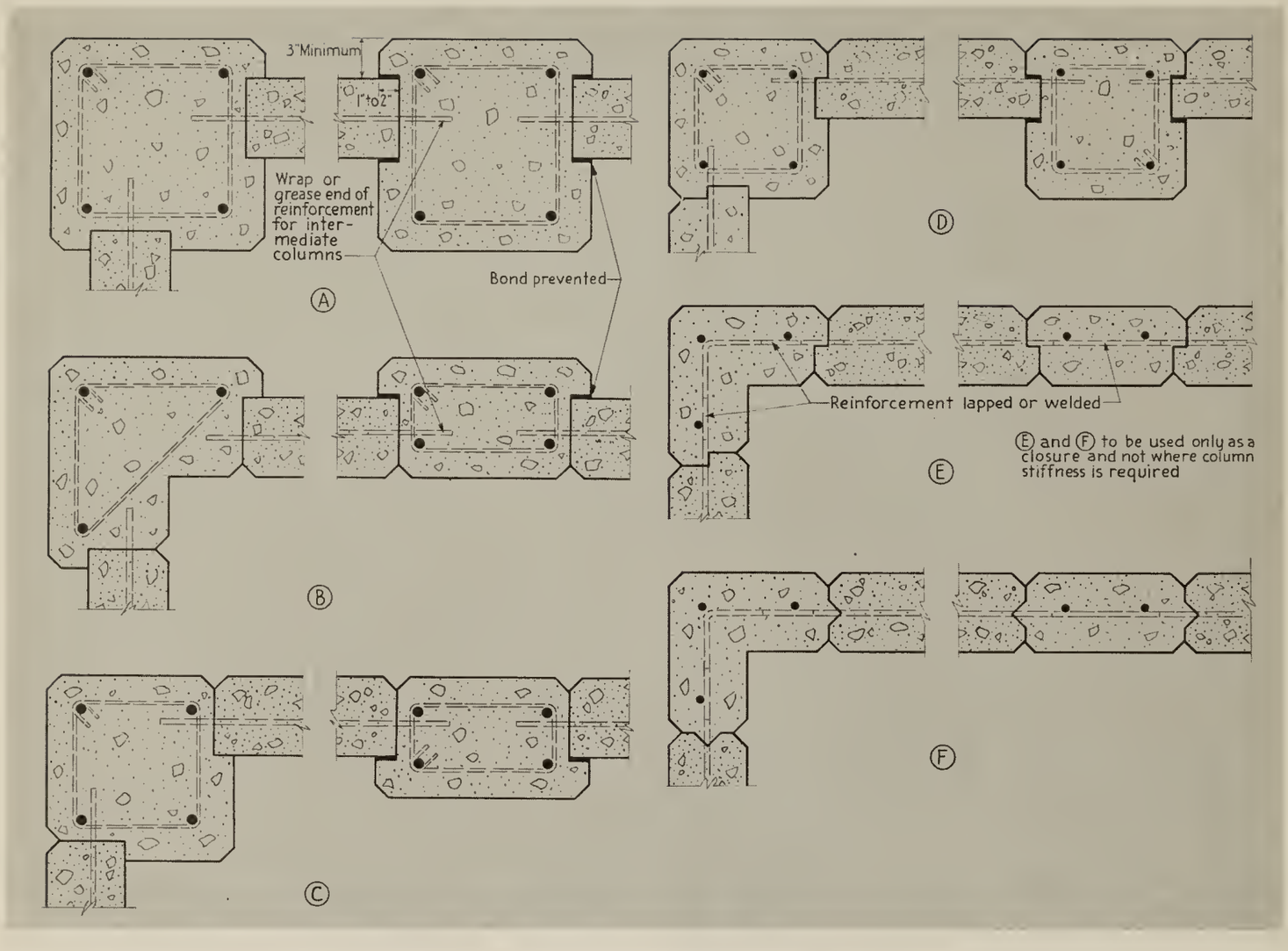
Joints similar to ship-lap or tongue-and-groove have been used but such joints are unnecessary and add to the cost.

Another needless detail which adds to the cost is the use of a hinge to prevent the slab from sliding during erection. If the lifting force is applied vertically there is no tendency for the panel to slide and even if the lifting force is at a slight angle there will be little or no sliding. If the lifting equipment is such that there is a considerable horizontal component, this can be offset by attaching snubbing lines to the dowels near the bottom of the panels. Hinges have the disadvantage of making it impossible to adjust the alignment of the panels after placing without cutting the hinges. Also, they may split the



Foundation—Wall Joints. **These are typical joints subject to many variations. *A* and *C* are the simplest and most commonly used. The offset from the floor level in *D* and the offset in the wall in *E* are to reduce the possibility of leakage. However, if the foundation or lower wall is sloped or offset slightly as shown in these sketches so that there is no horizontal surface to catch the water, there is little possibility of leakage. Certainly there is no more possibility of leakage at this point than with any unit masonry wall.**

The panel will be tilted onto the strip of premolded joint filler and then the remainder of the joint pointed with cement mortar.



Column—Wall Joints. **A to D are typical joints for use where movement at the joints is desired. They can also be used for rigid joints by lapping the reinforcement and omitting the bond-prevention material. Note that even where movement is desired at intermediate columns the corner columns are bonded to the wall panels. V-joints should be used wherever the face of the wall is flush with the column.**

concrete from the edge of the panel. If hinges are used they must be set with extreme accuracy.

To eliminate the possibility of leakage, too much emphasis is often placed on the making of this horizontal joint rather than on other details. Any of the joints mentioned above will be at least as watertight as the usual joint between masonry walls and their supports. To prevent leakage it appears that emphasis should be placed on other details. The supporting member should not extend in a flat plane even a fraction of an inch beyond the face of the wall. If there is any extension, it should be sloped so that any water running down the wall will drain away from the joint.

Normally rain will not penetrate very far into a vertical joint or crack even though it may be relatively wide. If, under severe conditions, rain does penetrate into the crack and runs down, no damage will be done if it drains outside of the building at the bottom of the joint. Trouble may develop, however, if any water accumulating at the bottom of the vertical joint drains into the building rather than to the outside. To reduce this possibility, the top of the floor may be an inch or so above the horizontal joint. Experience has shown that with such an offset, panels can be tilted into place without difficulty.

Columns

There are probably more variations in column details than in any other feature of tilt-up construction. Columns may be placed either after or before the panels are tilted. Both methods have their advantages. On the large majority of jobs, however, the columns are cast after the panels are in place. This permits the use of simple and

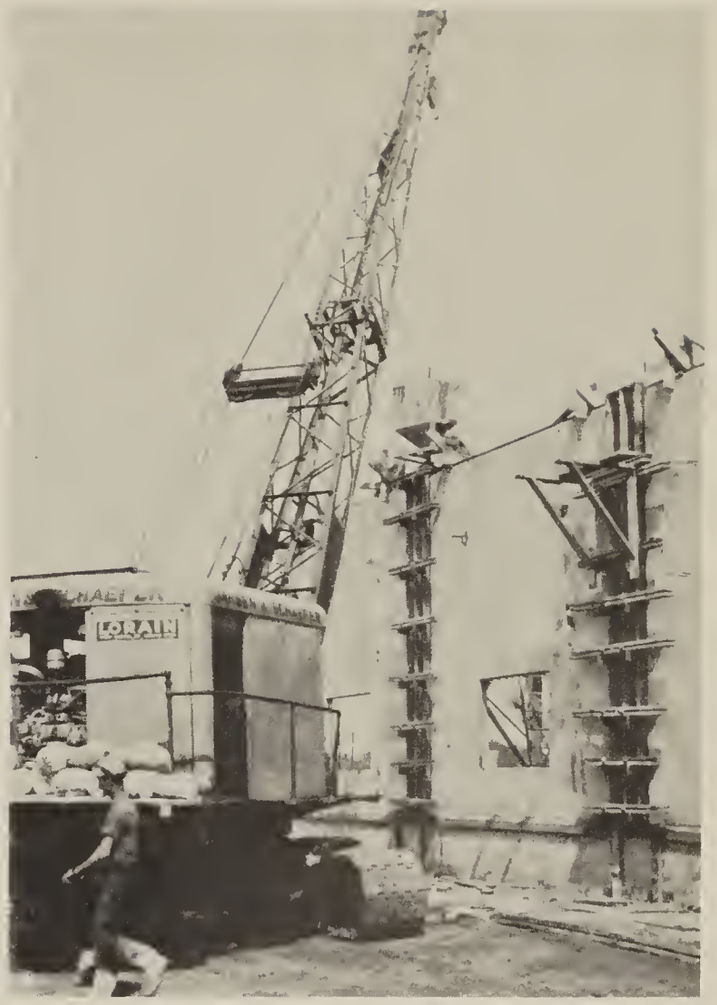
economical details and, since it is not necessary to have such exact dimensions as required when the columns are placed first, less care is required in forming and placing the panels. This is particularly true where the column overlaps the wall panel on both faces. The column forming is more economical when the panels are placed first. Casting the columns first has the advantage of eliminating or greatly simplifying the temporary bracing of panels and thus reduces the cost of bracing and time of erecting each panel.

Another major point of variation is whether the reinforcement or dowels from adjacent panels are fastened together or are arranged for relative movement. On the west coast, where earthquakes are considered in the design, adjacent panels are fastened together as rigidly as possible. Rigid connections have also been used throughout the country in residences and other small structures where the walls are not more than one or two panels long. For larger buildings in parts of the country where it is not necessary to design for earthquake forces, nearly all column connections are designed to allow relative movement between adjacent wall panels. This permits expansion and contraction of the panels, caused by moisture and temperature changes, without developing stresses which would tend to crack the walls. A survey of buildings constructed by the tilt-up method has shown that there is movement in the majority of joints between panels and columns and that cracks in the panels are extremely rare.

Where the columns are cast after the walls are in place, they may overlap the panels on one or both sides. This overlap hides any irregularities in the panel edges and variations in the planes of adjacent panels. Even though the space between panels may vary because of inaccuracies in panel dimensions or setting, the overlap permits uniform column width and repeated use of the column forms without adjustment. The possibility of leakage is also reduced by the overlap.

The overlapping edges of columns must be prevented from bonding with the wall panels to allow movement in the joint without cracking the lip. If the surface of the panel covered by the lip is smooth and true, bond can be prevented by coating it with any of the materials used for bond prevention in casting the panels. Under other conditions a membrane of some type should be used. This may consist of one or two thicknesses of paper, felt, premolded joint filler, cork gasket or similar material. This may be cemented to the panel to hold it in place during concreting. It may extend beyond the form and be trimmed off even with the lip after the forms are removed or, with rigid or semirigid material, it may be butted tightly against the form before placing the concrete.

It is sometimes desirable to have the column flush



Concrete for the columns is being delivered by a hopper bottom bucket on a crane. The column form is used to support a platform from which the workmen can guide the bucket and rod or vibrate the concrete in the column.

with the panels on one or both sides of the wall. In such case a V-joint or other definite rustication should always be used between the wall panel and the column. This rustication will hide and protect the crack which will form at this point; permit calking if necessary (quite unlikely); give a straight, true joint; prevent smearing of panels with leakage from concrete cast in the column; and break the wall surface so that variations in the planes of adjacent panels will be inconspicuous.

Where the panels are tied together rigidly by cast-in-place columns, the reinforcement from adjacent panels should be welded or lapped sufficiently to develop by bond the tensile strength of the bars.

The bars from adjacent panels, where relative movement is desired, must be coated or covered to prevent bond. If deformed bars are used, they must be wrapped with paper or some other material to be certain of pre-

The warehouse for Westinghouse Electric Supply Corporation at Toledo, Ohio shows the contrast between horizontally board-marked columns and steel troweled and tooled panels. Albert Hutchison, engineer. Henry C. Beck Company, contractor.

venting bond. Where plain bars are used as dowels, bond can be prevented by coating them with waterproof grease, bituminous material, or with the bond-prevention material used in casting the wall panels. The portion of the bars which is to extend into the column can be dipped into the liquid bond-prevention material before the dowels are set in the panels. Before the concrete is placed in the columns the bars should be checked to see that they are perpendicular to the plane of the edge of the column and wall panel, and are completely covered or coated. Some care must be used in placing the concrete to prevent removing the coating or covering. Since these bars will act in shear only, they need not extend very far into the column to develop their full strength. In some cases this extension has been as little as 2 in. although about 6 in. is more common. It should be sufficient to extend them just beyond the column reinforcement. A short extension gives satisfactory results, saves steel, reduces the possibility of bond and gives less interference with tilting.

Roofs

Any type of roof can be used with tilt-up construction. The problem of waterproofing the top of the joint between columns and panels is eliminated if an overhanging roof is used. Although the movement at these points is so small that it will not affect any type of roof construction it may be sufficient to cause trouble from leakage unless precautions are taken. The most common and simplest treatment is to use calking compound in the joint between column and panel. This performs satisfactorily when properly maintained. Where the wall extends above the roof, a continuous raggle should be cast in the wall and columns for the roof flashing.

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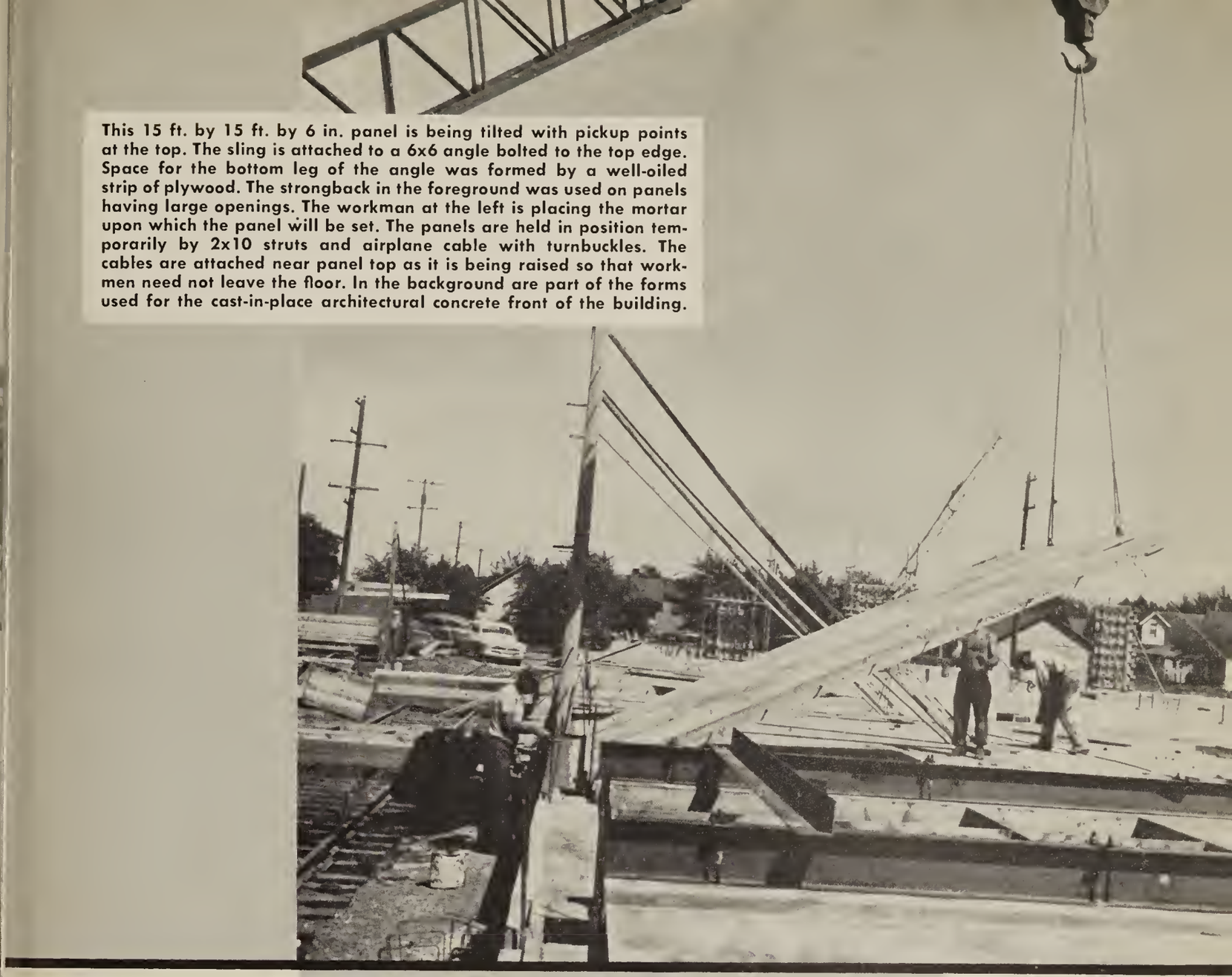


This 15 ft. by 15 ft. by 6 in. panel is being tilted with pickup points at the top. The sling is attached to a 6x6 angle bolted to the top edge. Space for the bottom leg of the angle was formed by a well-oiled strip of plywood. The strongback in the foreground was used on panels having large openings. The workman at the left is placing the mortar upon which the panel will be set. The panels are held in position temporarily by 2x10 struts and airplane cable with turnbuckles. The cables are attached near panel top as it is being raised so that workmen need not leave the floor. In the background are part of the forms used for the cast-in-place architectural concrete front of the building.

TILTING

Equipment

Tilting may be done with simple hand-operated equipment or with various kinds of power equipment up to large specially designed cranes. The choice will depend upon the size of the job and the cost and availability of equipment which the contractor owns or can rent. For small jobs where only a few panels can be made ready for tilting in one day, some contractors have found it more economical to use hand equipment with a higher labor cost than to bring in power equipment. Where a considerable number of panels are ready for tilting at one time, power equipment will speed up the job and generally prove more economical. Any equipment can be used which can give both vertical and horizontal movement either simultaneously or alternately.

The most popular power equipment is a crane. Other equipment used includes a winch and A-frame either on the ground or mounted on a truck, specially designed hydraulic jacks and even power shovels. In some localities a specially designed crane with a vacuum mat for handling tilt-up panels is available for rental.

Although it is desirable for lifting equipment to have a capacity equal to the weight of the panel, this is not necessary. Work can be done with equipment which has a capacity equal to little more than one-half the weight

This hand-operated tilting mast is simple and inexpensive. On small jobs the cost of extra labor involved is more than offset by the saving in cost of equipment. The short 6x6 angle used for attaching the equipment to the panel does little to distribute the pickup stresses indicating that any method of direct attachment to the top edge is satisfactory with small panels. A slight modification for wider lateral distribution of pickup load would be advantageous.

of the panel. Capacity above this acts as a safety factor and is useful in aligning the panel in case it is not tilted into the exact position desired. Even with a minimum lifting capacity, considerable adjustment of final position can be obtained by jacking or by prying with a pinch bar or timber.

Tilting

Power tilting equipment may be operated from either inside or outside the building. Each position has its advantages and disadvantages. The selection will depend upon the specific job conditions and equipment available.

This steel angle will be attached to the panel by the bolts projecting from the top edge to aid in distributing the lifting stresses.

Operation from inside the building provides a smooth even surface for the equipment but heavy equipment may overstress the floor where it is designed for only light loads. This difficulty has been overcome on large buildings by casting only that portion of the floor needed for a casting platform. On small buildings, tilting from the inside causes more interference with other work on the job and conversely other construction operations or material storage may interfere with movement of the equipment. Working from the inside places the equipment in the most advantageous position when the greatest lifting force is required. This occurs when the lifting starts, at which time the boom is practically vertical rather than extended at an angle as is necessary when the equipment is outside the building.

The leads from the lifting equipment should be kept practically vertical at all times to avoid sliding the panel on the slab. There will then be no need for hinges or other devices to prevent sliding.

The vertical alignment of the panels can be checked with a spirit level attached to a straightedge about the height of the panel. A plumb bob can also be used as a simple and easy way of checking vertical alignment. Before the panel is raised, the plumb line is attached to the top of the panel so that it will hang a couple of inches from the face of the wall. This distance is measured accurately before tilting. After the panel is raised, its plumbness can be checked by measuring the distance from the line to the face of the wall at the bottom.

Lifting Attachments

There are many satisfactory ways of connecting the panel to the lifting equipment. In making a selection for a particular job, consideration should be given to the lifting equipment; size of panel; openings in panel; lifting stresses; cost of material and installation of inserts, etc.; cost of reusable material; and time required to attach and detach lifting equipment.

The simplest connection is made by making a 180 deg. hook in the end of two of the vertical reinforcing bars in the panel and having part of these hooks protrude from the top edge of the panel. This detail has been used satisfactorily for panels as much as 12 ft. in height. With small panels the sling from the hoist may be fastened directly to these hooks. Fastening the hooks to a rigid

A vacuum pad is used as the attachment to the panel. This reduces the stresses in the panel and does not disfigure the surface. An extra line is attached to the top edge of the panel as a safety measure and can be used to handle the panel after it is tilted. In some instances, pads have been used which cover nearly the entire surface thus practically eliminating bending stresses in the panel while tilting.

Extra I-beams have been welded on top of the legs of the conventional strongback to increase their stiffness. Extra connections between the panel and the spreader are made through plates at the edge of the panel. The 4x4 timbers attached to the foundation wall guard against the panel slipping off the foundation while being tilted. All of these details may be useful but are not generally necessary.

cross member or spreader to which the sling is attached will reduce the bending stresses in the longitudinal direction of the panel. This longitudinal bending may be minimized by bolting a channel or angle to the top edge of the panel and attaching the sling to it. Channels or angles may also be bolted to the edges of the panel to reduce the bending in the vertical direction of the panel.

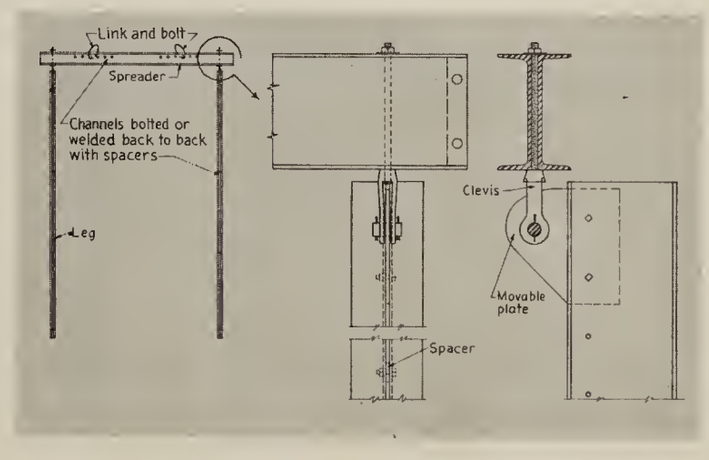
Splitting of the concrete by lifting bolts or hooks in the edge of the panel should be prevented by placing a reinforcing bar in the panel parallel to and about 2 in. from the edge.

The equipment that has been used most frequently to reduce lifting stresses in the panel is a strongback. While there is a growing trend to eliminate the use of strongbacks because of the attachment bolts in the finished wall surface and also because experience has shown that panels can be lifted without them, many contractors continue to use them. The strongback usually consists of 2 legs extending from top to bottom of the panel and a cross member near the top. The legs are bolted to the slab at 2 or more points and the sling is attached to the ends of the legs or to the cross member. Each leg consists of a deep I-beam or 2 channels, back to back, with spacers. Channels are preferred since they can be attached to the panel with a single bolt at each attachment point while the I-beam requires 2 bolts at each point. The extra bolt adds to the cost of material and placing, and has the disadvantage of further disfiguring the wall.

A strongback which can be easily adjusted to a wide range in size and shape of panel can be constructed for very little more than a nonadjustable one. Suggested details for such an adjustable strongback are shown at right. Even though such a strongback is to be used, considerable time and money will be saved by locating pickup points on any one job so that the strongback can be used with as few changes in adjustment as possible.

Strongbacks are generally attached by removable bolts embedded in the concrete, the nuts remaining in the concrete. To permit removal, the bolts must be coated or wrapped. Form lacquer or similar material is preferred to oil or grease for coating since the latter may cause slight surface staining. The material is easily applied by dipping. Giving the bolts a half turn within 24 hours after the concrete is placed will aid materially in their final removal. Ordinary bolt stock is seldom perfectly round which sometimes makes it difficult to remove and replace

***Strongback.* A strongback such as this permits easy adjustment to fit panels of any size. The pickup points can be any place on the vertical legs, the legs can be moved horizontally on the spreader and the spreader can be moved along the legs. The sling can be attached to the spreader at various points by moving the links and bolts.**



The three-point pickup part way down the panel shown in this view reduces bending stresses. The hooks near the top of the rig clamp over the top of the wall and steady it during setting. Half columns are cast integrally with and at the edges of each panel. The half columns are fastened together at the top and grout placed between them. The reinforcing bars extending from the panel will join with bars extending from the floor slab and then concrete will be cast to complete the strip of floor slab along the wall. Notice the slots rather than holes in the attachments for the braces lying on the panel in the foreground.

them for attaching the lifting rig. This can be overcome by using stud bolts which are not removed from the concrete until the panel is in place.

Some contractors have used form ties rather than bolts for attaching strongbacks. These are economical and give a minimum of disfiguration to the wall surface.

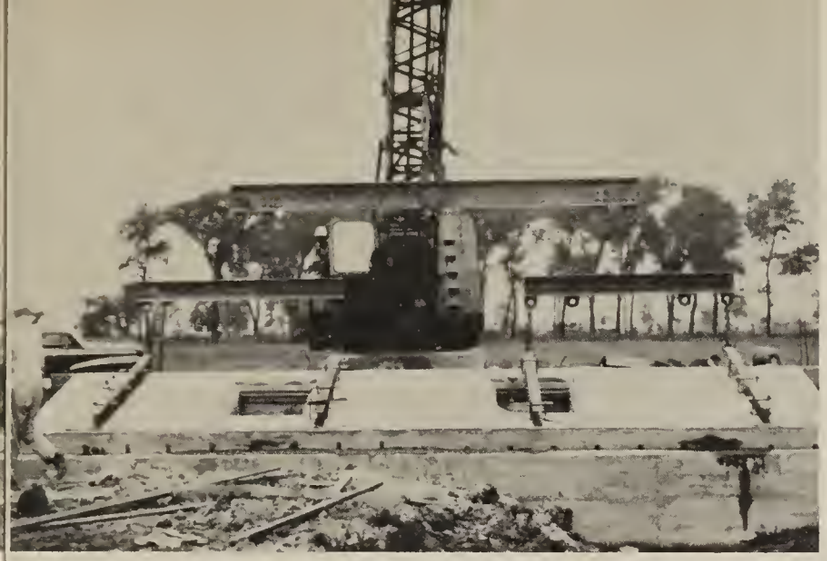
Vacuum mats have been used very satisfactorily for picking up panels. They can be located on the panels so as to give negligible lifting stresses, thus permitting early tilting and minimum reinforcement. The surface will not be disfigured by bolt holes.

Braces

As with all other details of tilt-up construction, there is great variation in the methods of bracing the panels until the columns are cast. Braces vary from a 2x4 with simple attachment to the top of the wall and to the ground or floor, to pipes with adjustable length and special fittings at the ends. In selecting the braces to be used, consideration should be given to safety, speed and ease of use, initial cost and number of reuses.

From the safety standpoint, consideration should be given not only to preventing the panel from being blown

Three special hydraulic jacks operated in unison were used to tilt this panel. Snub lines attached to the top of the panel prevented it from tilting too far until the wood braces were secured.

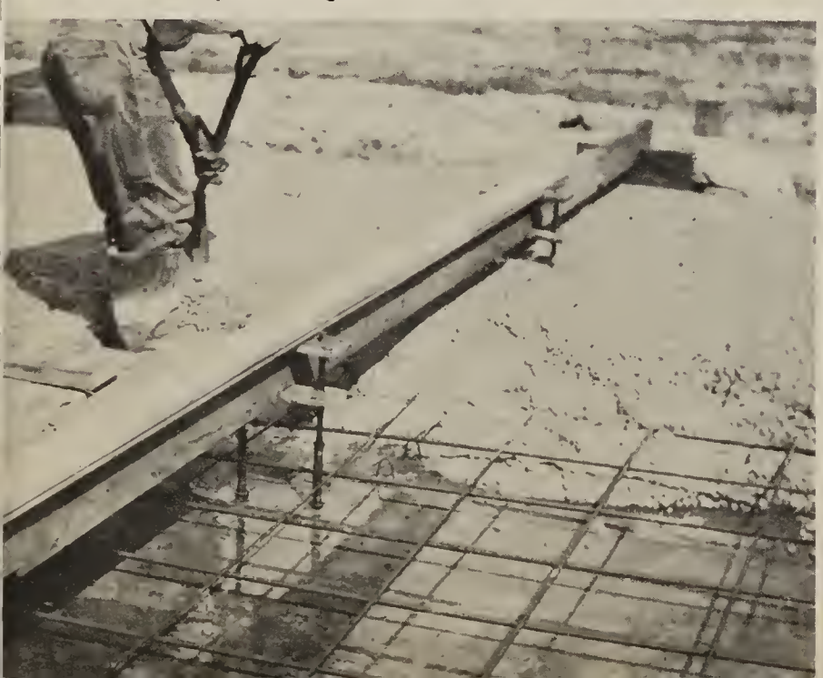


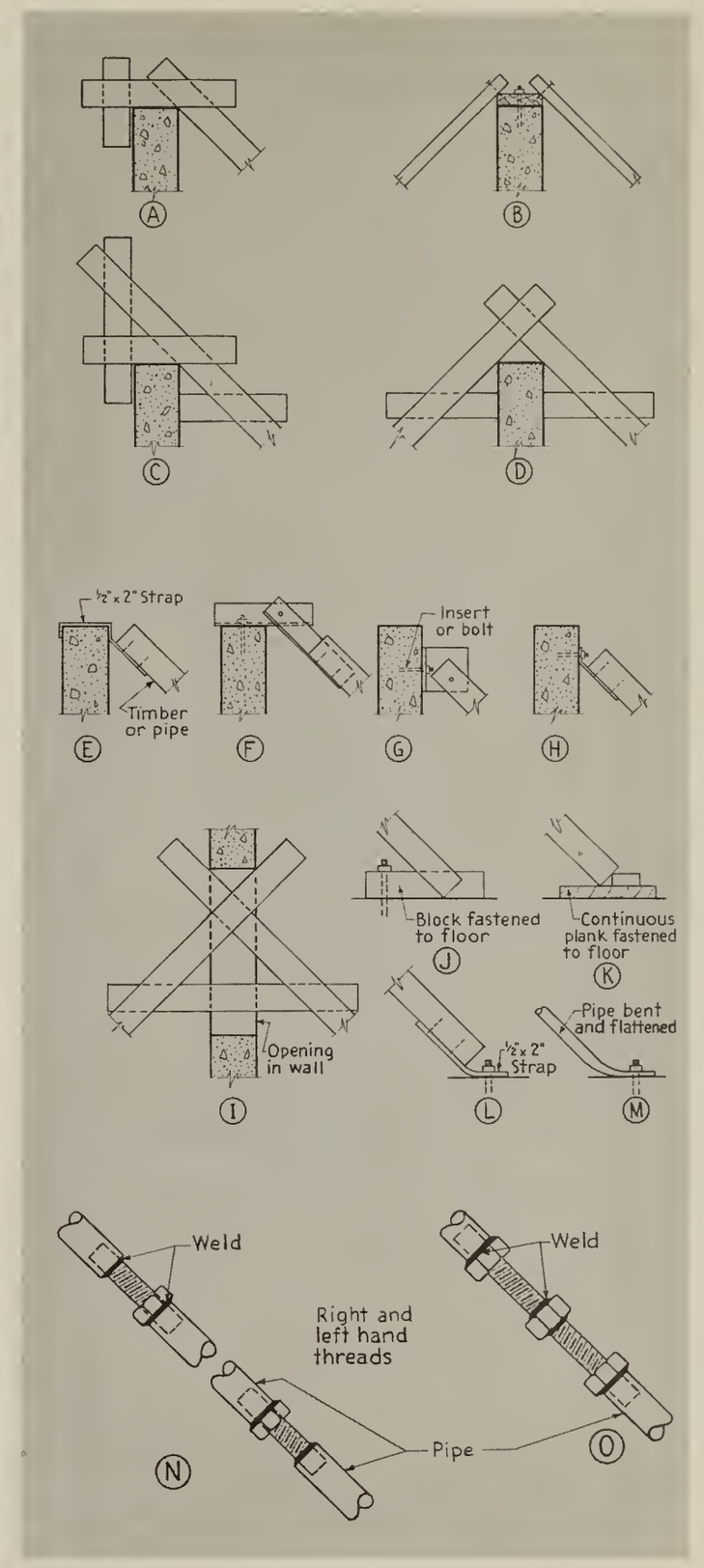
This elaborate arrangement of equalizers can be used to advantage on long panels but is not needed for the average job. Two sets of attachment points on each cross member provide for some variation in pickup points.

down, but also to the safety of the men during erection. Obviously it is best if the workmen have little or no work to do on the top of the erected wall to attach the braces.

The wood braces with simple end connections at first appear to be the most economical but this is not always true if the overall job is considered. The special braces with some means for close adjustment of length, such as a turnbuckle type, and with special end connections can save considerable time in plumbing the panel and in attaching and detaching the braces. With some types, the top connection can be made before the panel is in an upright position. The time saved in attaching and plumbing is particularly important because it means a saving in time of the erection crew and equipment used on each panel. With the turnbuckle type, accurate plumbing can be done while the lifting rig is being fastened to the next panel.

Bolts for attaching a strongback are held in position by a templet during placing of the concrete. Many times bolts and inserts can be held in place satisfactorily by wiring to the reinforcement although a templet will usually result in more accurate positioning.





Braces. **Sketches *A* to *I* show typical connections of braces to walls and *J* to *M* show connections to the floor. Any of these may be combined or used with other details such as stakes driven into the ground. For economy, braces must be set and adjusted quickly after the panel is tilted. The fine adjustment possible with turnbuckles such as shown in *N* and *O* result in rapid erection and release of tilting equipment before final plumbing of panels. The turnbuckles, being relatively weak in bending, should be placed near the end of the brace.**

Adjustable Braces.

1—A pipe brace with a great adjustment in length. The top section telescopes into the lower section and the two are held together with a bolt. The holes for this adjustment can be seen in the upper piece of pipe. Fine adjustment is made with the turnbuckle at the bottom.

2—A close-up of the standard turnbuckle.

3—A turnbuckle attached to the end of a timber brace.

4—An adjustable brace in which the pipe, with nuts welded to the ends, forms a turnbuckle with the eye bolts at the ends. Beyond this pipe brace can be seen two timber braces with metal connections at the end.

5—Another type of adjustable pipe brace. The threaded portion is stiffer than the standard turnbuckle, so it can be placed nearer the center of the brace without materially reducing its stiffness. It is more convenient for workmen when placed at this height.

Six-in. tilt-up walls are combined with a cast-in-place architectural concrete front on this Grange Cooperative Wholesale warehouse at Spokane, Wash. Designed by T. Carson and built by L. E. Blumer Company.

INSULATION

As in other types of construction, the heat insulation value of tilt-up walls may be increased by the use of furring, blanket insulation, rigid insulation and plaster in the usual manner after the wall is erected. It may also be increased by using lightweight concrete and, of course, by increasing the thickness. Other ways are by casting the panel on rigid insulating board which bonds to the panel; using lightweight aggregate concrete for the interior face of the panel; and making the wall as a sandwich with insulating material between the two layers of concrete.

Nailing strips are usually cast in the panel when the wall is to be insulated in the conventional manner after tilting.

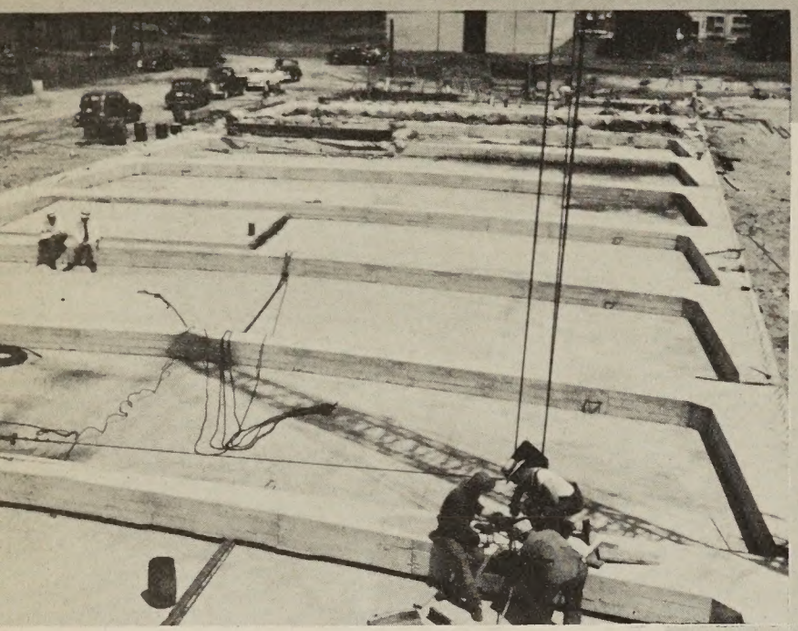
When concrete is cast on rigid insulation the bond may be increased by driving nails through the insulation so they will protrude into and bond with the concrete. If the insulation does not give a satisfactory wall surface, plaster may be applied after the wall is in place.

Part of the wall thickness (inside face) may be made of concrete having a high insulating value, such as that made with aggregates of very light weight. If the inside face of the wall is the bottom of the panel, the insulating concrete is placed and screeded to the desired thickness. A delay of 2 to 4 hours is necessary before placing the regular concrete to prevent its penetration into the insulating concrete. Finishing and erection then proceed in the usual manner although extra curing and drying before tilting have proved worthwhile. To avoid crushing or spalling the bottom edge during tilting, it is desirable to use the regular concrete for the entire thickness of the panel for a distance of about 2 in. from the bottom edge. A 2-in. plank temporarily set inside the bottom edge form can be removed after the insulating concrete has set and will thus provide space for the regular concrete. The thickness of the insulating concrete will depend upon the insulation desired. From 1 to 6 in. has been used in panels with total thickness of 6 to 8 in. However, about 2 in. of insulating concrete will provide sufficient insulation in most cases.

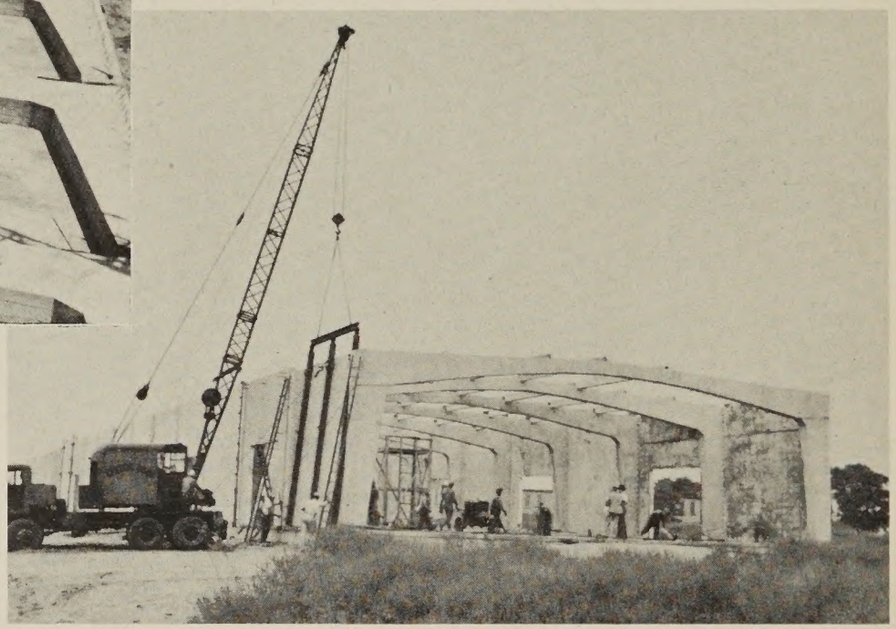
The insulating concrete, of course, will not withstand the abrasion and bumping that will occur in some occupancies. A finish coat of plaster may be applied to the wall which will give the conventional plaster surface.

The sandwich-type panels are made by placing a layer of concrete, a layer of insulation and then a layer of concrete, the last two layers being placed before the first one has hardened. Reinforcement is placed in both layers of concrete and the two layers are fastened together by ties. These may be single bent bars or wires or may be strips of mesh or expanded metal. Sometimes the strips are bent to form a channel or Z-section. The insulating material should bond to but not be adversely affected by the fresh concrete. It should also act as a vapor barrier.

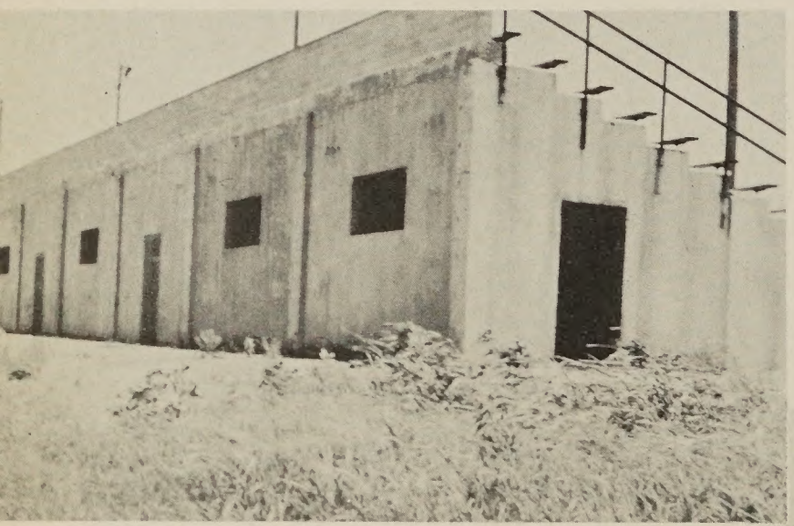
Special Uses of



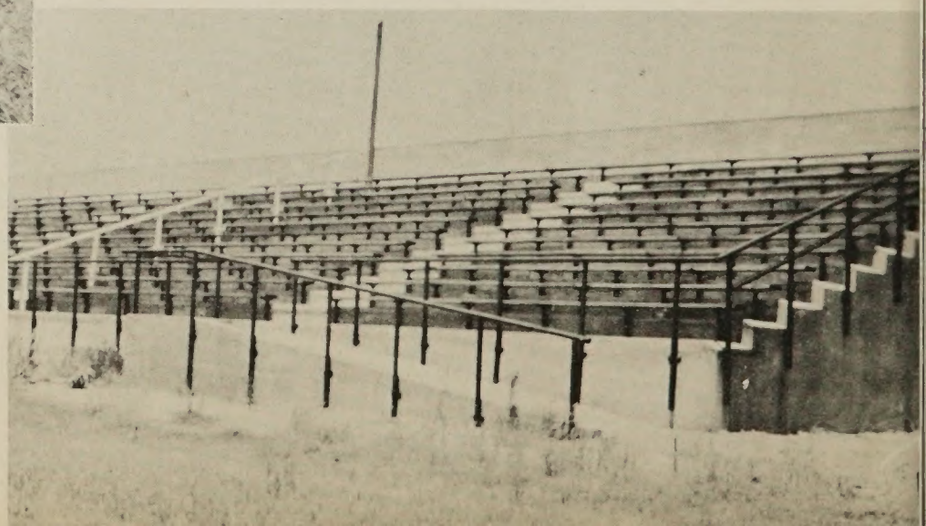
Warehouse at South Bend, Indiana. Both the 19-ft. high walls and the 60 ft. span rigid frame bents were tilted into place. Precast purlins support a precast concrete roof deck. Place & Company, owner and contractor. William S. Moore, engineer.



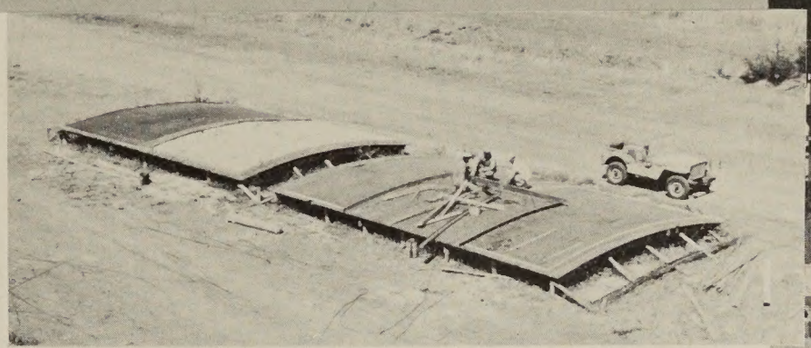
Trench silo on W. D. Caldwell farm, Prairie City, Iowa. A continuous steel channel was slipped over the top of the tilt-up panels to keep them in line and was anchored to concrete deadmen on outside of silo before backfill was placed. The temporary inside braces supported the wall during backfilling and were removed as the silage was placed.

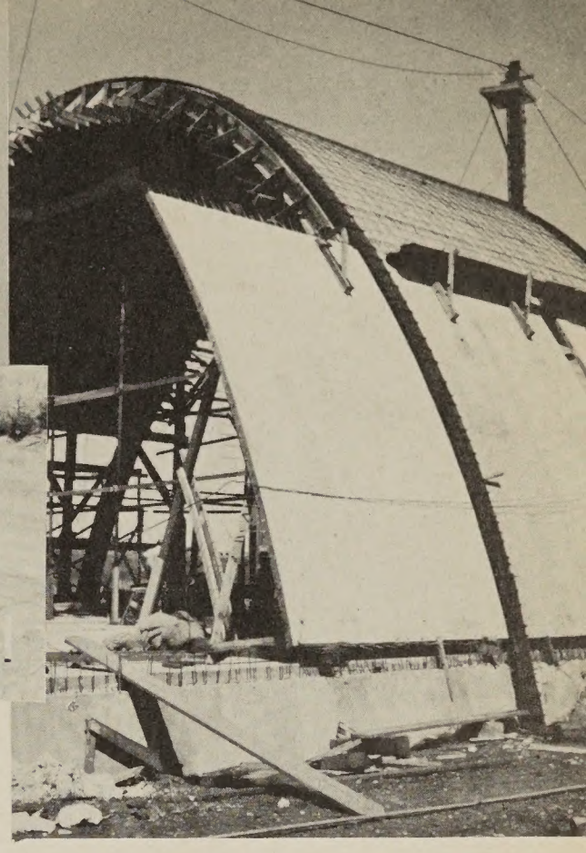


Grandstand at Richardson, Texas. The bents and walls, except parapet, are of tilt-up construction on this economical grandstand. The treads and risers are of L-shaped precast units. Chappell, Stokes and Brenneke, engineers.

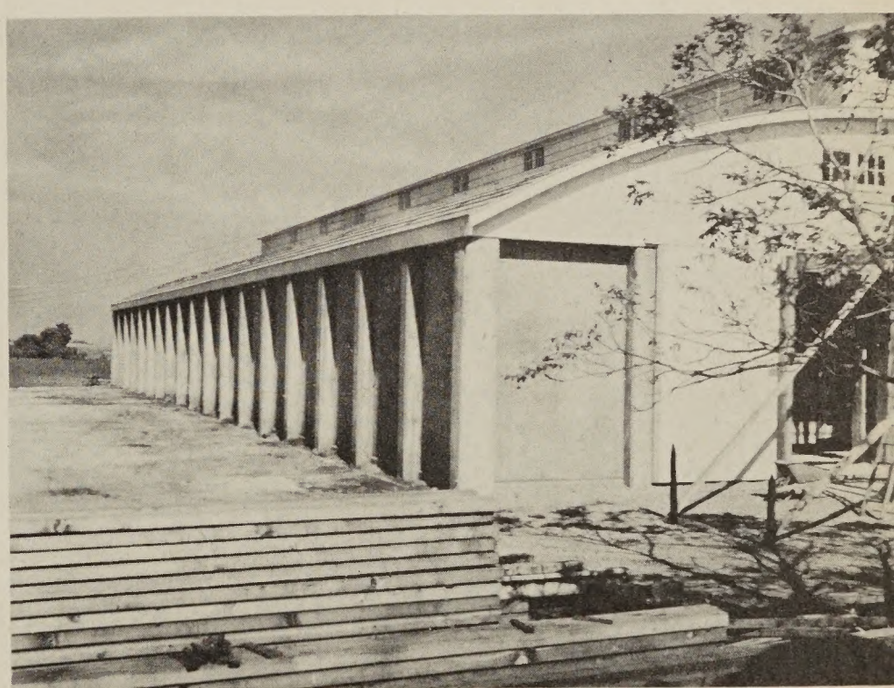


Tilt-Up Construction

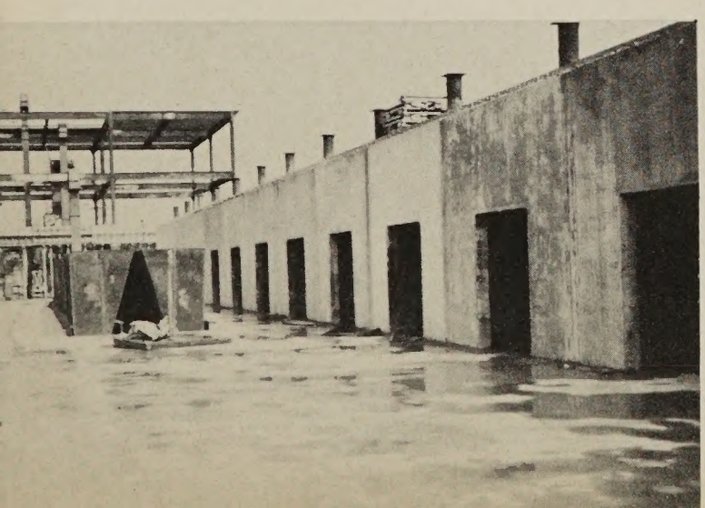




Warehouse for St. Louis Waste Material Company at Fort Worth, Texas. The lower part of this reinforced concrete thin-shell roof was precast on a nearby platform, lifted into place and made an integral part of the cast-in-place structure. Precasting reduced the formwork and eliminated the difficult placing of concrete between forms. The upper part of the shell was cast in place with formwork on the underside only. Bailey Company, engineer-contractor.



Grain storage building at Jordan, Iowa. This 60x180-ft. building with tilt-up walls is for bulk storage of grain. Temporary bulkheads are placed inside the doors as the building is filled. William N. Nielsen, architect-engineer. A. Sterner Company, owner-contractor.



A few of the 37 grain storage bins with tilt-up walls being built by the Grain Processing Corporation at Muscatine, Iowa.

The activities of the Portland Cement Association, a national organization, are limited to scientific research, the development of new or improved products and methods, technical service, promotion and educational effort (including safety work), and are primarily designed to improve and extend the uses of portland cement and concrete. The manifold program of the Association and its varied services to cement users are made possible by the financial support of over 65 member companies in the United States and Canada, engaged in the manufacture and sale of a very large proportion of all portland cement used in these two countries. A current list of member companies will be furnished on request.

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